B Lifetime and Mixing in DØ

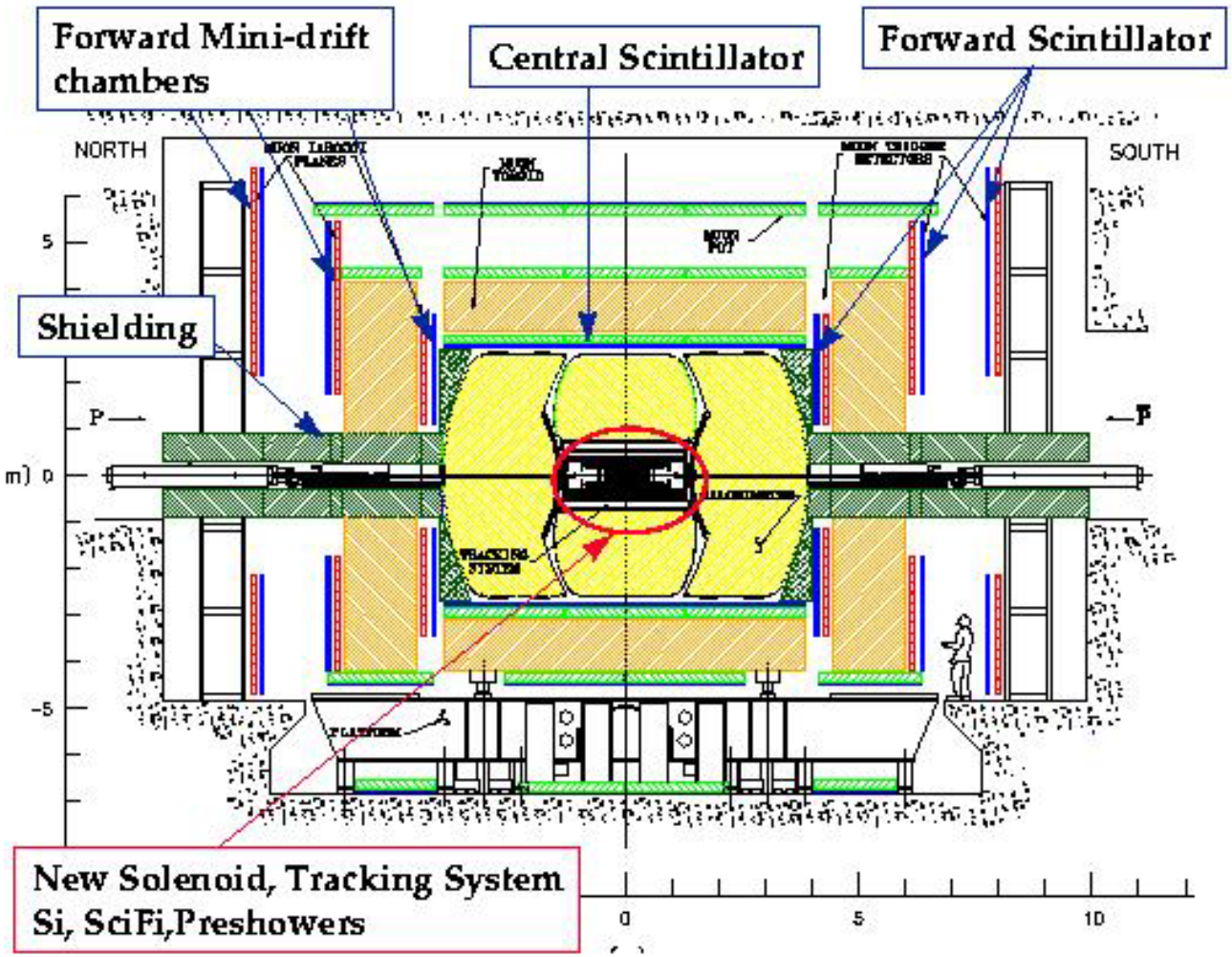
Sergey Burdin (Fermilab)
for the DØ Collaboration

WIN03 / Lake Geneva, October 6-11, 2003

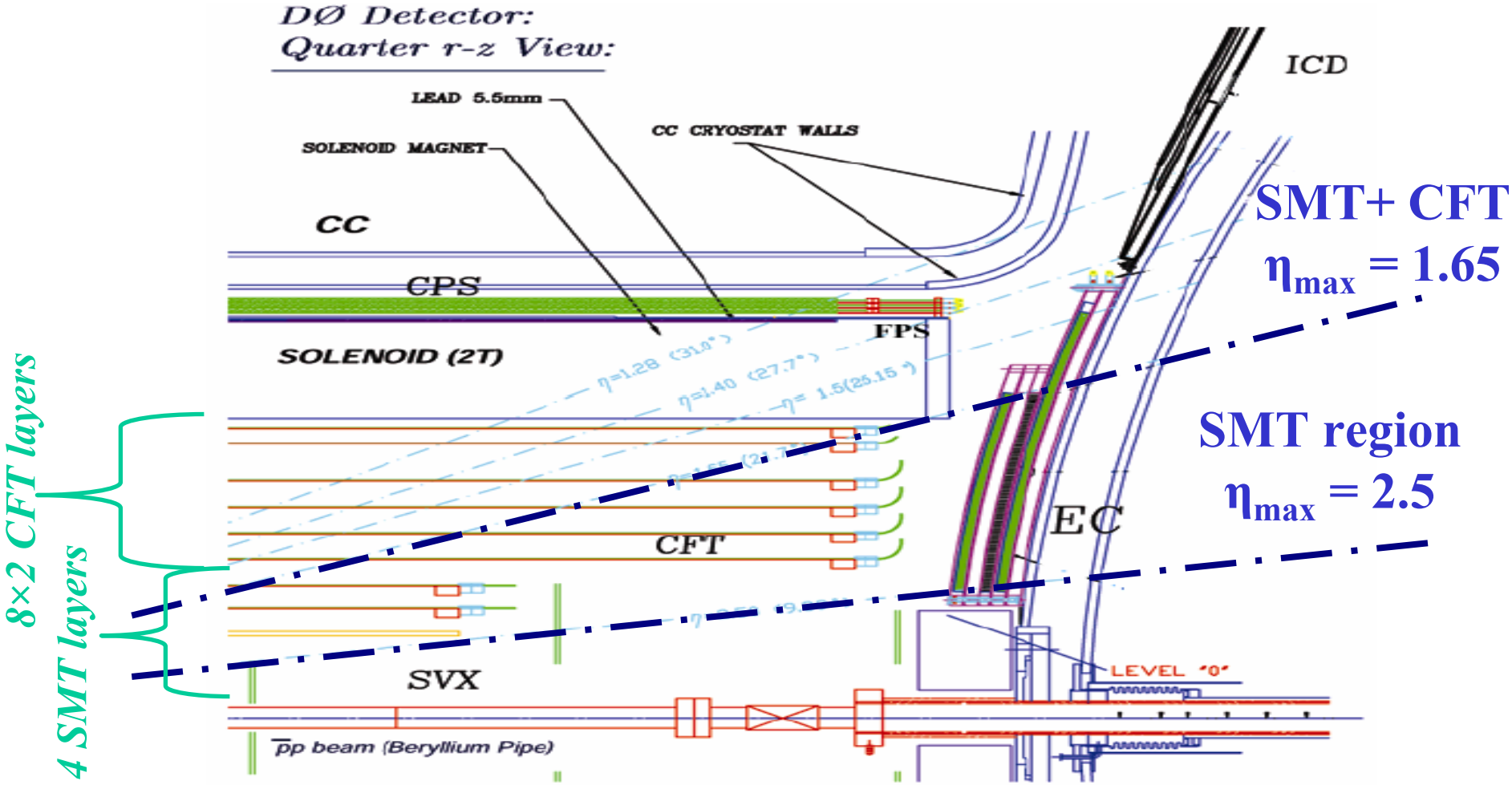
Outline:

- ✓ DØ Detector
- ✓ B-hadron lifetime measurements
- ✓ Prospects for B_d & B_s mixings

Detector


Forward Mini-drift chambers
Central Scintillator
Forward Scintillator
Shielding
New Solenoid, Tracking System
Si, SciFi,Preshowers
NORTH
SOUTH
5
-5
0
5
10

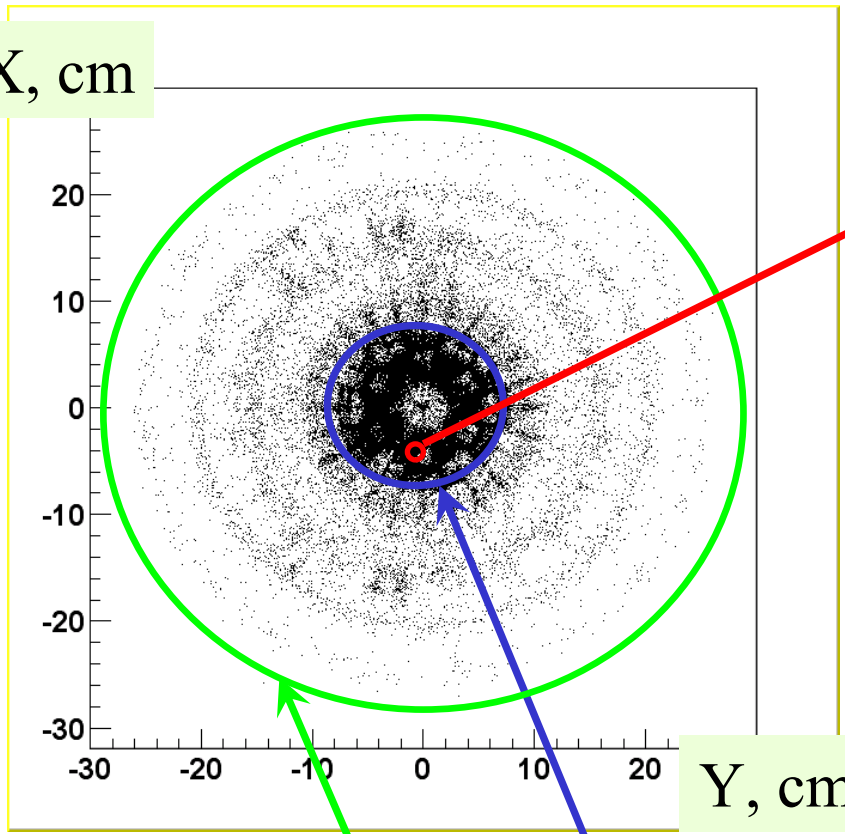
Tracker

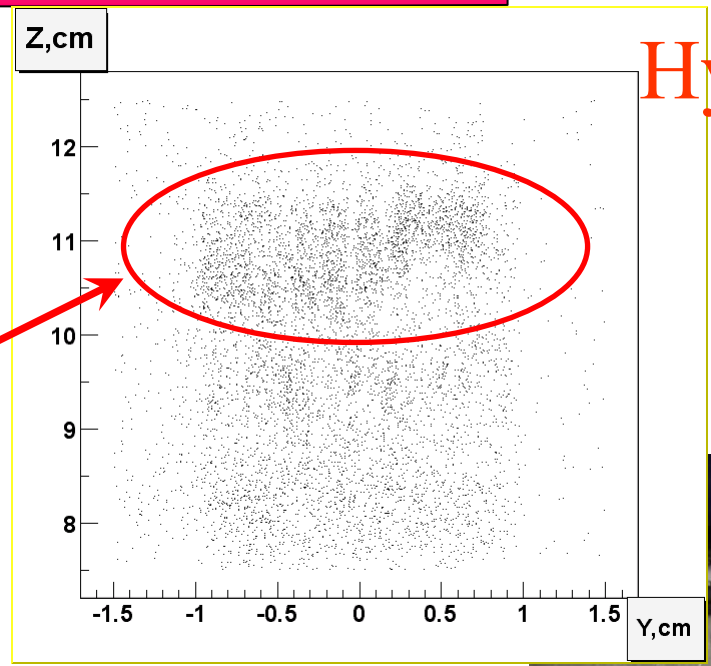


Trigger: muon+track covers $|\eta|<1.8$

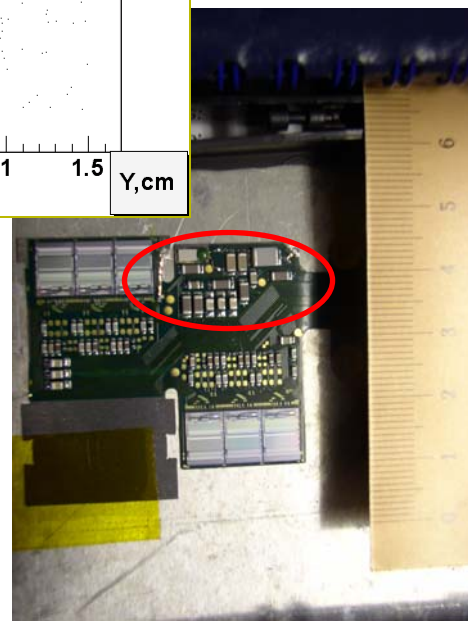
Image of Tracker from γ-conversions

Very large data sample



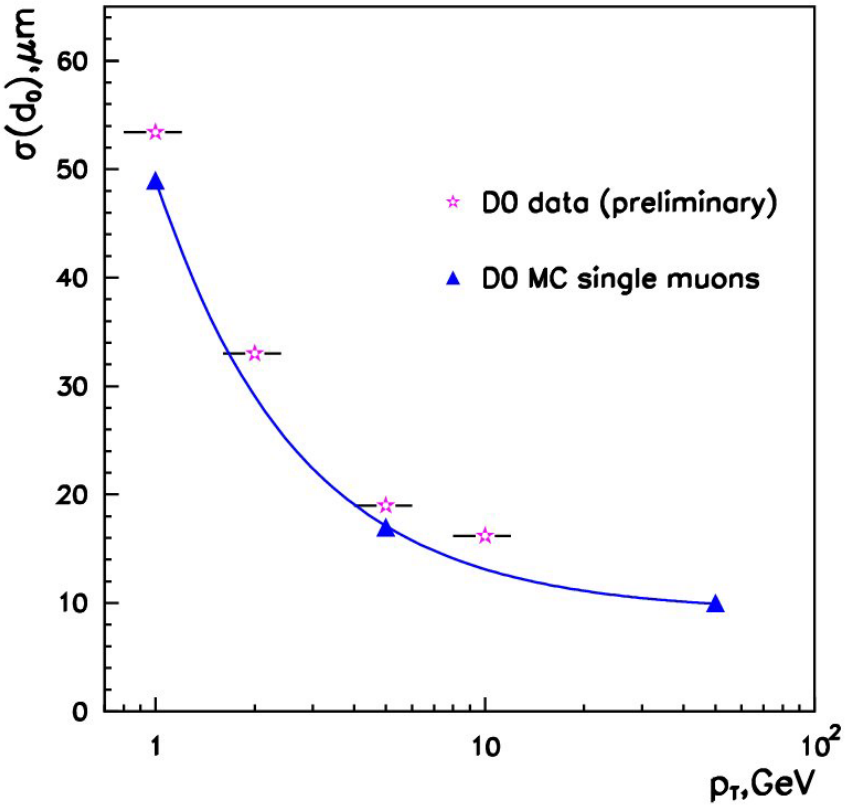


can be used to tune the description of material in the tracker



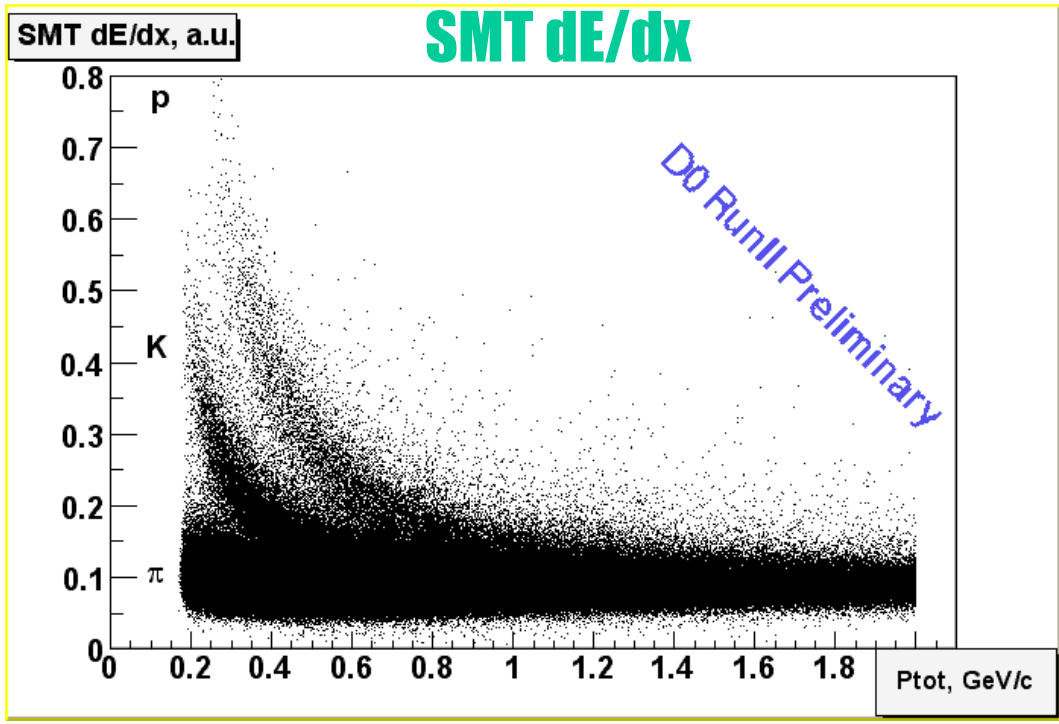
Tracking Performance (1)

Impact Parameter Resolution



σ(DCA)≈53μm @ P_t=1GeV
and better @ higher P_t

SMT dE/dx



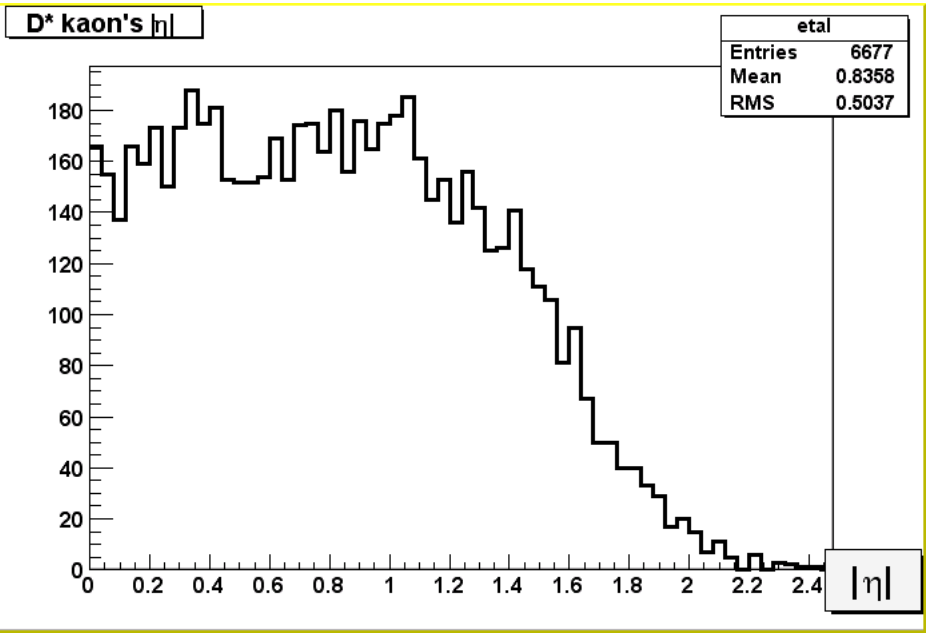
Is not used yet for PID

Can provide

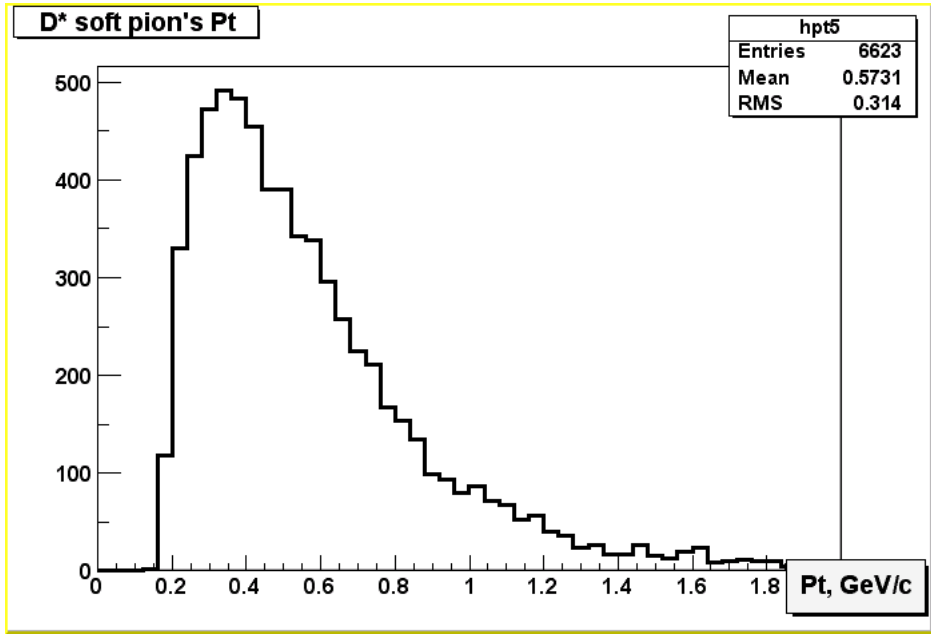
- K/π separation for P_{tot}<400 MeV
- p/π separation for P_{tot}<700 MeV

Tracking Performance (2)

|η| for kaons from $D^* \to D^0\pi$



Pt spectrum of soft pion from $D^* \to D^0\pi$



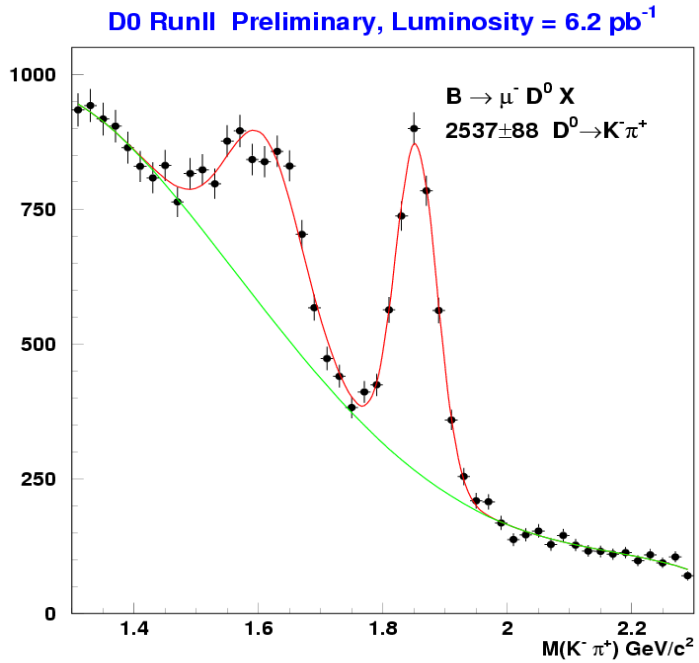
Tracks are reconstructed

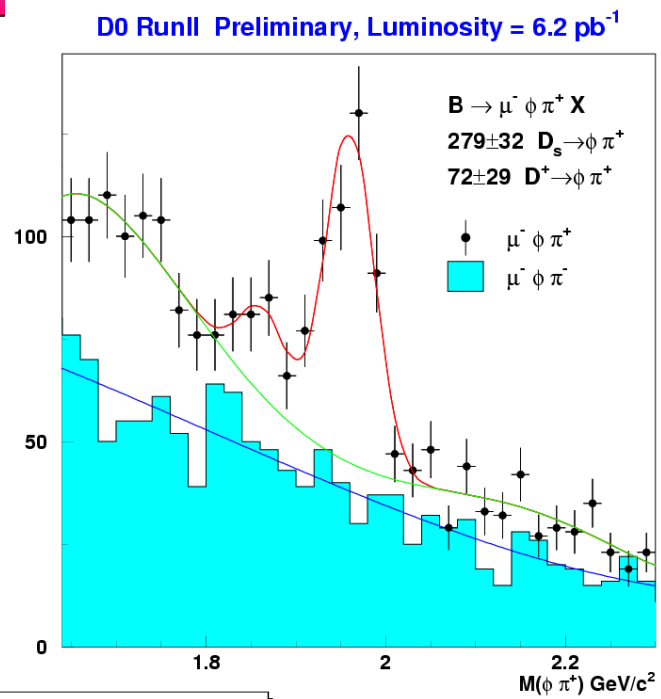
- **in wide η limits**
- **starting from P_t=180 MeV**

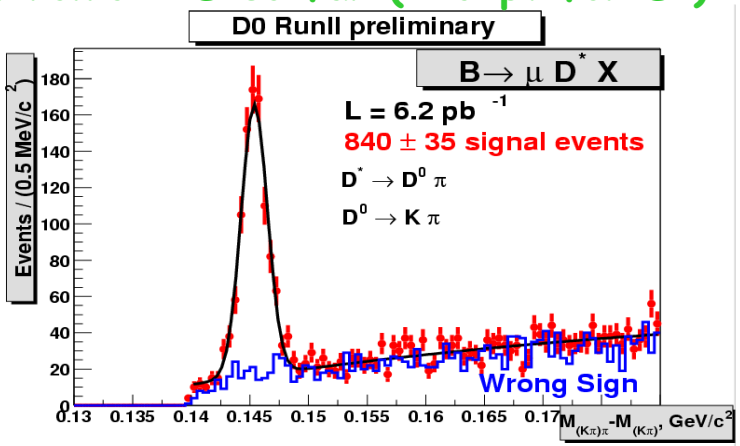
Efficient muon system & tracker & tracking give us large sample of semileptonic B decays

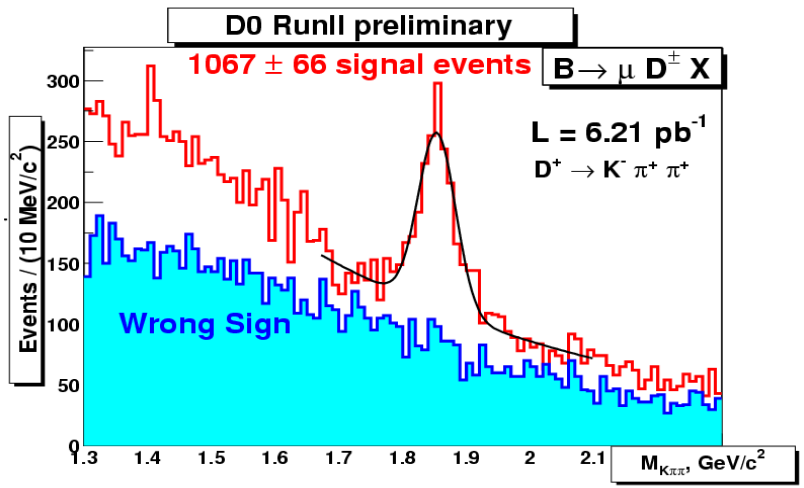
Large B Semileptonic Sample

- ✓ **Muon:**
  - Pt > 2 GeV/c
  - Ptot > 3 GeV/c
  - nSMT > 1
  - nCFT > 1
- ✓ **Charged tracks:**
  - Pt > 0.7-1 GeV/c
- ✓ **Secondary Vertex**
  - $L_{xy} / \sigma_L > 4$
  - $\cos(\theta(L,P_D))>0.95$
- ✓ **no hadronic PID so far (except for $D^{\pm}$)**









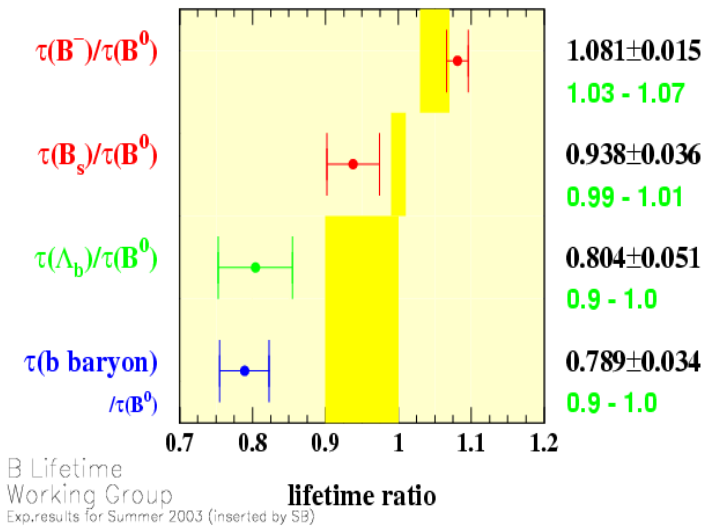
History of the B Lifetime Measurements

Predictions

Report of the B Physics at the Tevatron Workshop (12/2001)

- ✓ $\tau(B_d)/\tau(B_s)=1\pm0.01$
- ✓ $\tau(\Xi^0_b)\approx\tau(\Lambda_b) < \tau(B_d) < \tau(\Xi^-_b) < \tau(\Omega_b)$
- ✓ $\Gamma(\Lambda_b)-\Gamma(\Xi^-_b)\approx0.11\pm0.03 ps^{-1}$
- ✓ $0.9< \tau(\Lambda_b)/\tau(B_d) <1$

Comparisons



Experimental Results

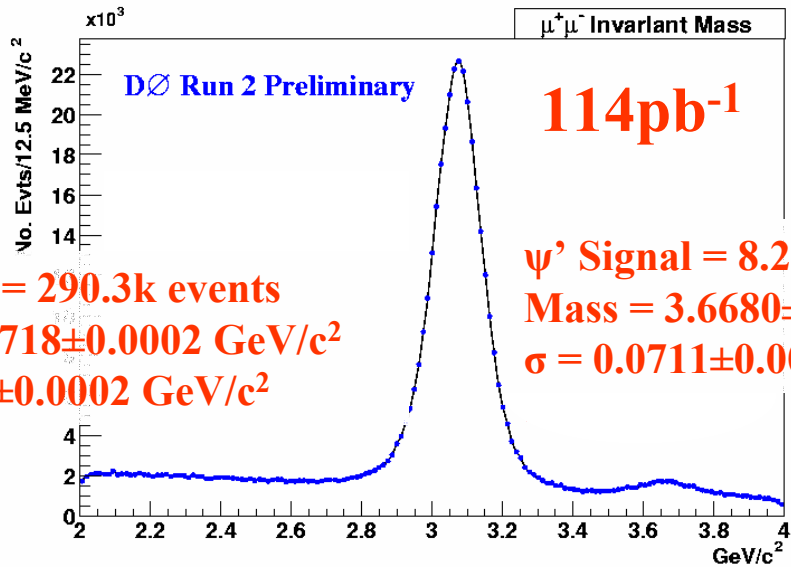
- ✓ $\tau(B) = 1.573\pm0.008 ps$
- ✓ $\tau(B^0) = 1.534\pm0.013 ps$
- ✓ $\tau(B^+) = 1.652\pm0.014 ps$
- ✓ $\tau(B^+)/\tau(B^0) = 1.081\pm0.015$
- ✓ $\tau(B_S) = 1.439\pm0.053 ps$
- ✓ $\tau(b_{baryon}) = 1.210\pm0.051 ps$
- ✓ $\tau(\Lambda_b) = 1.233^{+0.078}_{-0.076} ps$

B Lifetime Group (Summer 2003)

B Lifetime from Inclusive B→J/ψ+ X

Method

- ✓ Use $J/\psi \to \mu^+\mu^-$ for tagging, vertex constraint, Pt determination:
  - ☺ Clean signal
  - ☺ Large statistics
  - ☺ Good vertex resolution
  - ☺ Good momenta resolution
- ☹ Large prompt J/ψ contamination
- ☹ Need Pt correction factor from MC



J/ψ Signal = 290.3k events
Mass = 3.0718±0.0002 GeV/c²
σ = 0.0741±0.0002 GeV/c²

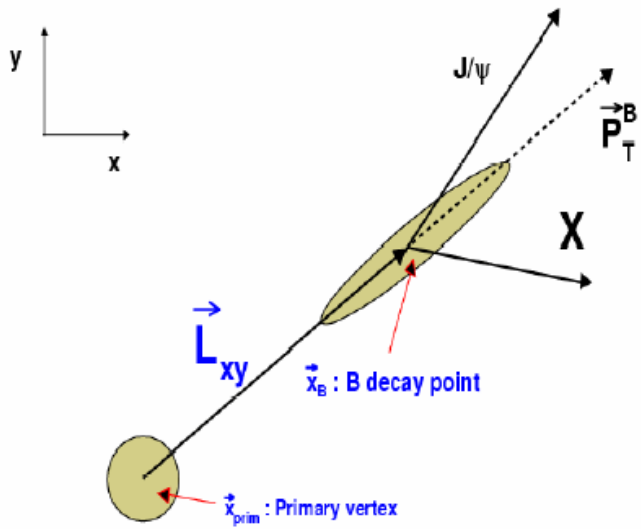
ψ' Signal = 8.22k events
Mass = 3.6680±0.0021 GeV/c²
σ = 0.0711±0.0022 GeV/c²

B Lifetime from Inclusive B→J/ψ+ X

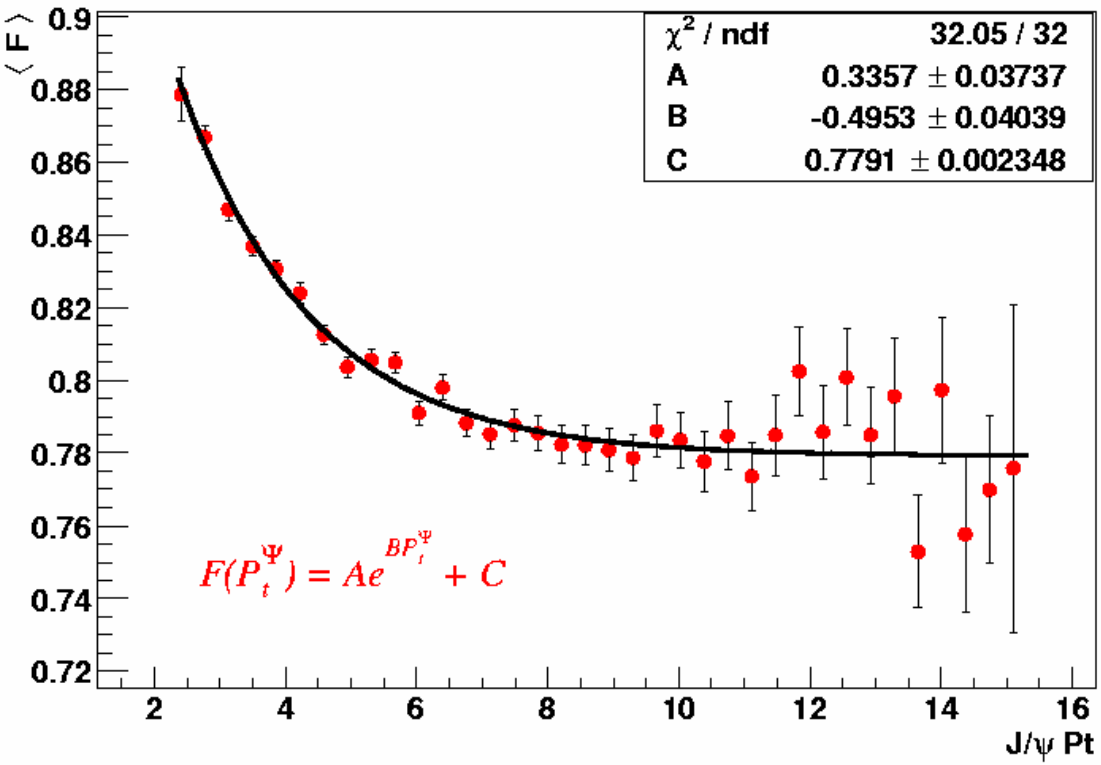
Corrections

$$L^B_{xy} = \mathbf{L}^B_{xy} \cdot \mathbf{P}^B_t / |P^B_t|$$

$$c\tau_B = \lambda_B = L^B_{xy}/(\beta\gamma)_t = L^B_{xy} \cdot M_B/P^B_t = (L^\psi_{xy} \cdot M^\psi_B/P^\psi_t)/\langle F(P^\psi_t)\rangle$$

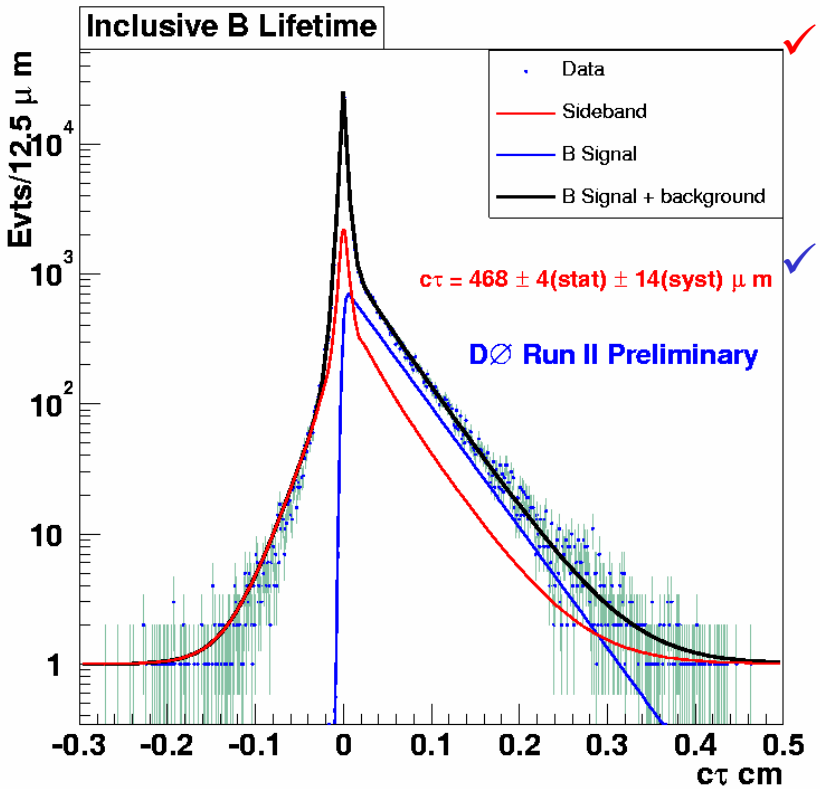


<F(Pψt)> from MC:



B Lifetime from Inclusive B→J/ψ+ X

Results



Proper Decay Length Shape:

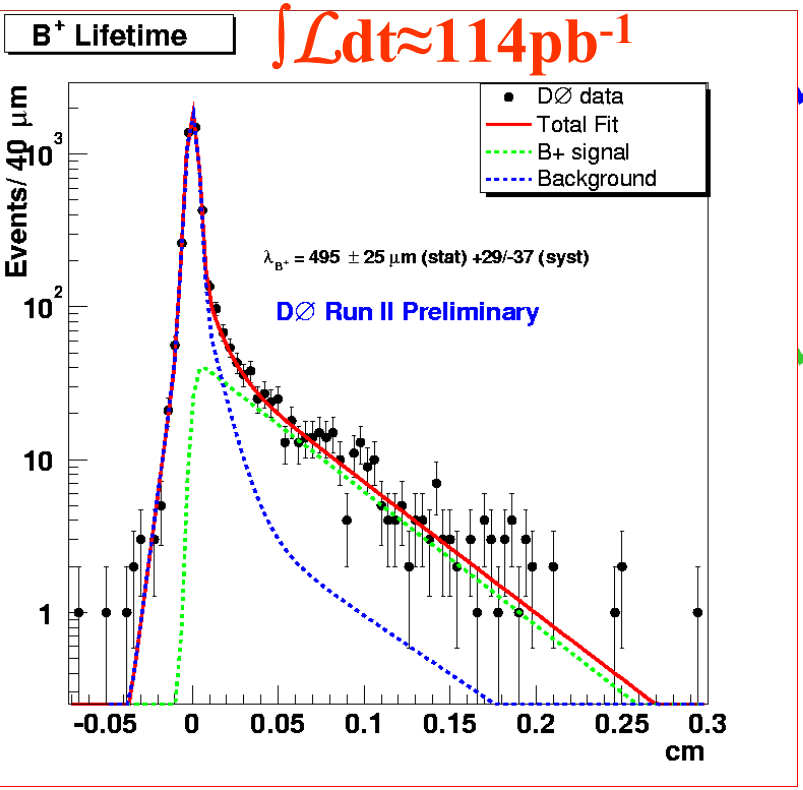
- ✓ **Background (19%):**
  - $G+Exp(+\tau_0)+Exp(-\tau_0)+Exp(+\tau_1)+Exp(-\tau_2)+const$
  - Shape from the J/ψ sidebands
- ✓ **Signal (81%):**
  - Prompt J/ψ (82%): $G+Exp(+\tau_0)+Exp(-\tau_0)$
  - J/ψ from b (18%): $Exp(\tau_B)\otimes G$

Correction factor gives one of the major contributions into the systematic errors

$\langle\tau_B\rangle = 1.562 \pm 0.013(stat) \pm 0.045(syst)$ ps

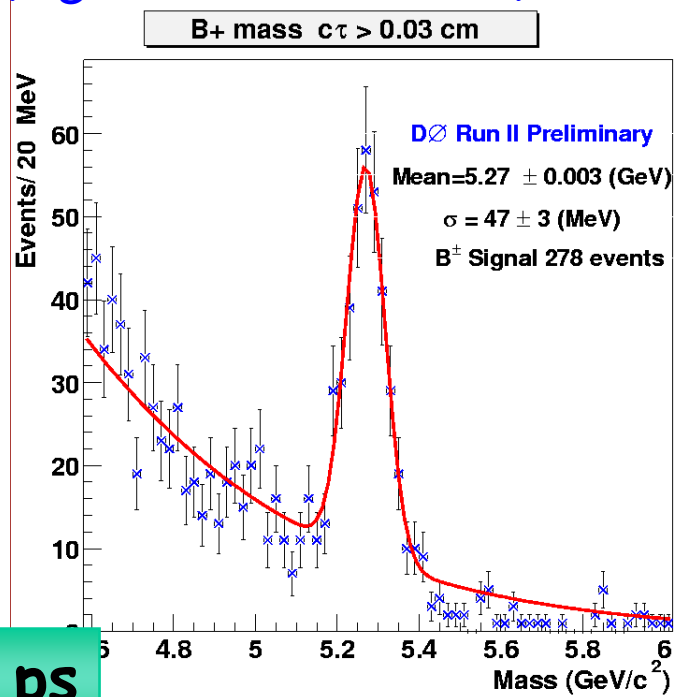
BLWG: $\langle\tau_B\rangle = 1.573 \pm 0.008$ ps

$B^{\pm}$ Lifetime from $B^{\pm} \rightarrow J/\psi K^{\pm}$



Proper Decay Length Shape:

- ✓ Background from B-sidebands:
  - ➢ $G + Exp(+\tau_1) + Exp(-\tau_2) + Exp \otimes G$ (B_s contamination)
- ✓ Signal:
  - ➢ $Exp \otimes G$

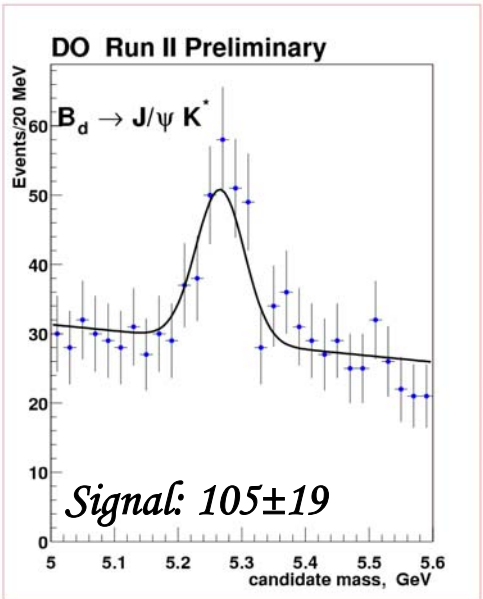


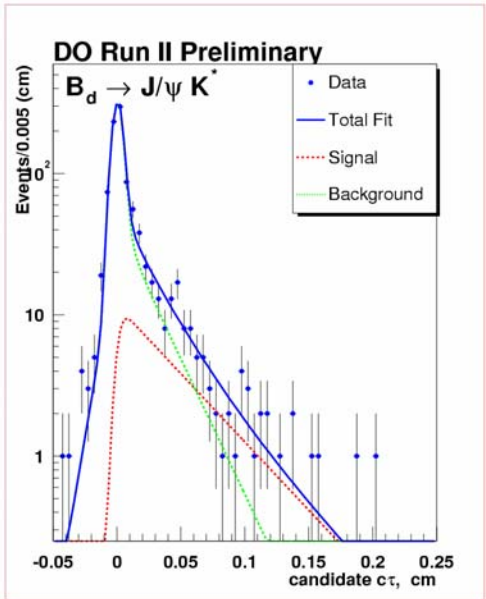
Fully reconstructed → No Correction Factor!

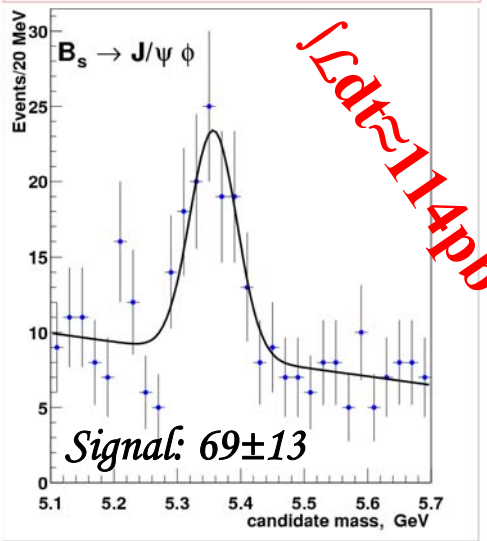
$\langle \tau_{B^{\pm}} \rangle = 1.65 \pm 0.083(stat) \pm 0.123(syst)$ ps

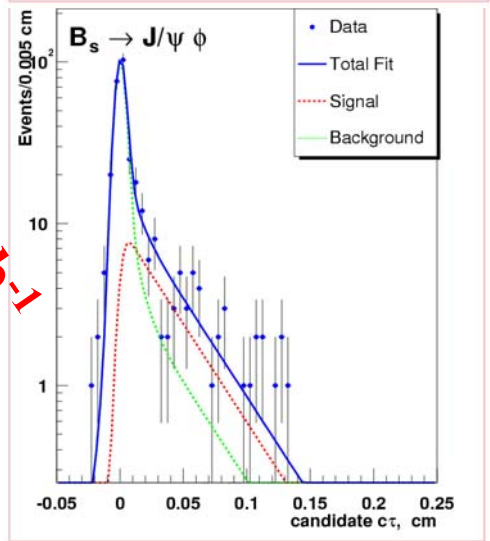
BLWG: $\langle \tau_{B^{\pm}} \rangle = 1.652 \pm 0.014$ ps

$B_{d,s}$ Lifetimes from $B \to J/\psi + K^{0*}, \phi$









Similar kinematics → Some systematic errors can be cancelled in ratio !

Proper Decay Length Shape:

- ✓ **Background:**
  - ➢ $G + \mathrm{Exp}(+\tau_1) + \mathrm{Exp}(+\tau_2) + \mathrm{Exp}(-\tau_3)$
- ✓ **Signal:**
  - ➢ $\mathrm{Exp}(\tau_B) \otimes G$

Results:

$\tau_{Bd} = 1.51^{+0.19}_{-0.17}\,(stat) \pm 0.20(syst)$ ps

$\tau_{Bs} = 1.19^{+0.19}_{-0.16}\,(stat) \pm 0.14(syst)$ ps

$\tau_{Bs}/\tau_{Bd} = 0.79 \pm 0.14$

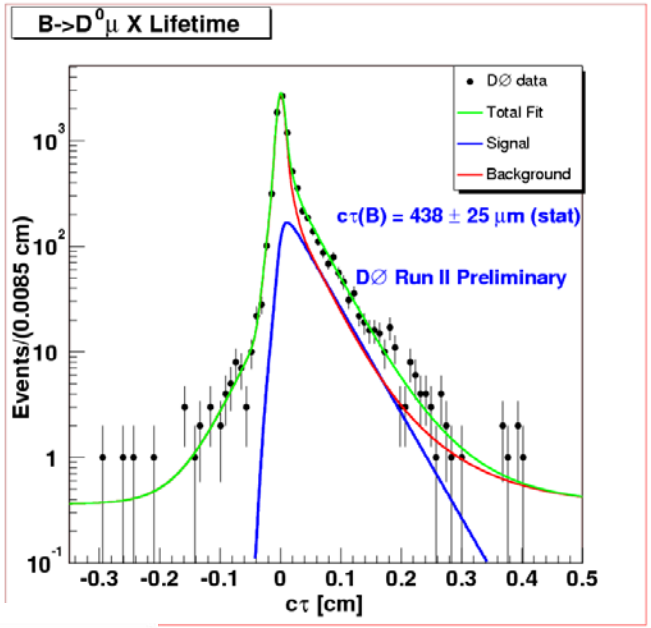
BLWG: $\tau_{Bd} = 1.534 \pm 0.013$ ps

BLWG: $\tau_{Bs} = 1.439 \pm 0.053$ ps

BLWG: $\tau_{Bs}/\tau_{Bd} = 0.938 \pm 0.035$

B Lifetime from Semileptonic Decays $B \to D^0 \mu X$

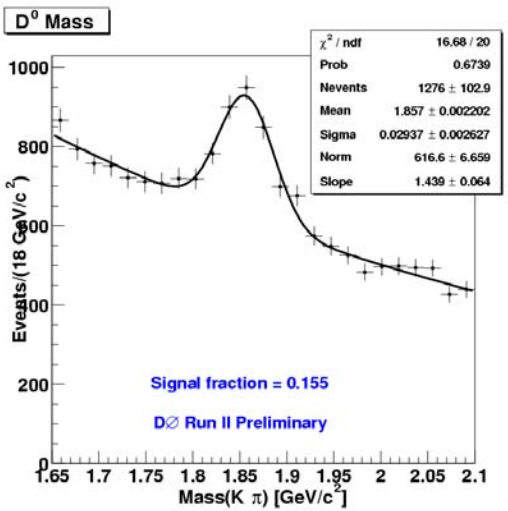
$\int \mathcal{L} dt \approx 12 pb^{-1}$



Benchmark measurement

Proper Decay Length Shape:

- ✓ Background:
  - ➢ $G + G + \mathrm{Exp}(+\tau_1) \otimes 2G + \mathrm{Exp}(-\tau_2) \otimes 2G + \mathrm{const}$
- ✓ Signal:
  - ➢ $\mathrm{Exp} \otimes 2G$



$$c\tau = L_{xy} M_b K / Pt_{(D+\mu)}$$

$$K = Pt_{(D+\mu)} / Pt_B \quad \textit{(from MC)}$$

Result:

$\tau_B = 1.460 \pm 0.083(\mathrm{stat.})$ ps

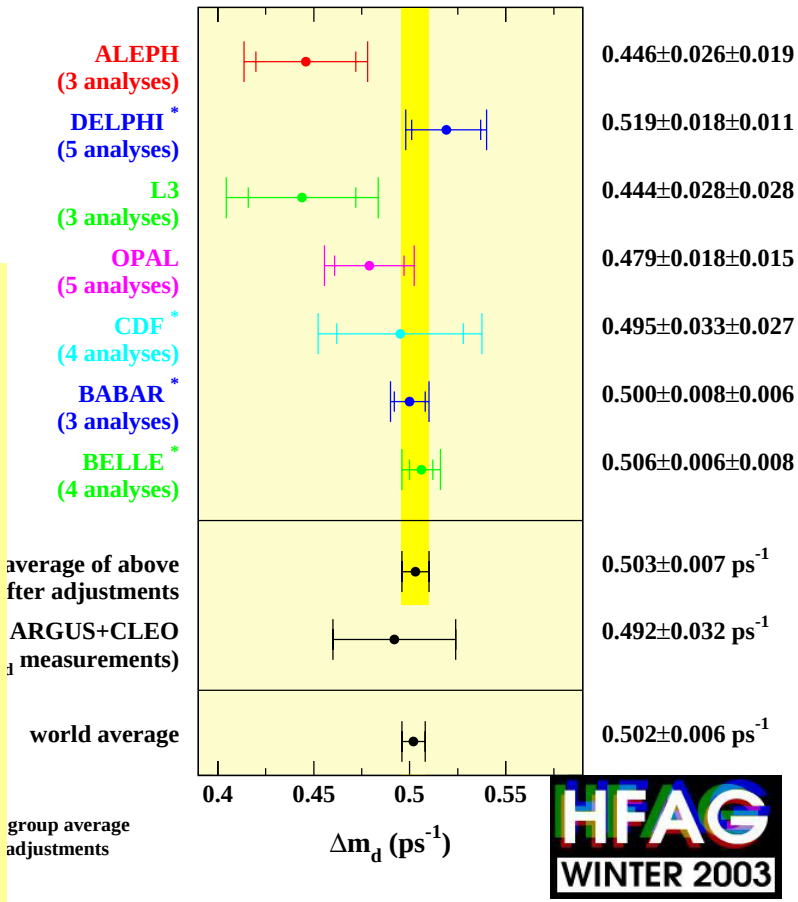
B mixing

- ✓ **ΔM -** *difference between B^0 mass eigenstates gives the oscillation frequency*
- ✓ Need for **ΔM measurement**:
  - ➢ Proper Decay Time
    - Time evolution of flavor
    - or time integrated rate (no CPV): $r = N(\overline{B^0})/N(B^0) \approx x^2/(2+x^2)$
      - $x = \Delta M / \Gamma = \Delta M \bullet \tau$
  - ➢ Initial State Flavor Tagging (ISFT):
    - efficiency: $\varepsilon=(N_{corr}+N_{wrong})/(N_{corr}+N_{wrong}+N_{notag})$
    - dilution: $D=(N_{corr}-N_{wrong})/(N_{corr}+N_{wrong})$
    - Significance of mixing measurement: $S \propto \varepsilon D^2$
  - ➢ Final State Flavor Tagging
    - from decay products

$B_{d,s}$ mixing

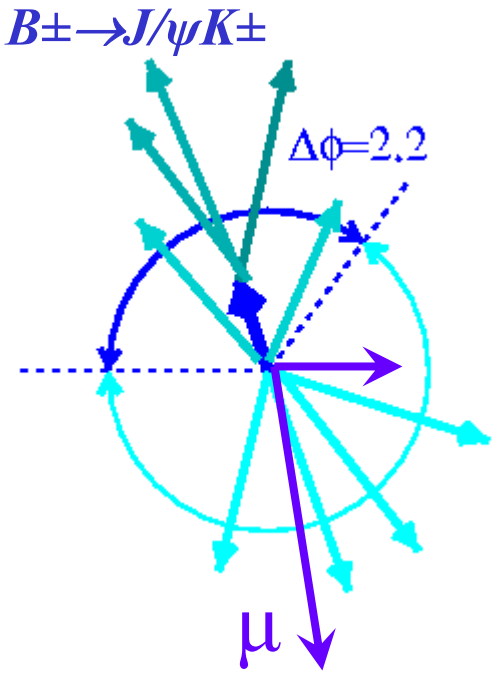
- *The B_d oscillation frequency is not too high:*
  - *Benchmark measurements*
  - *Semileptonic B decays can be used for frequency measurements*

$$\Delta M_d = 0.502 \pm 0.006\ ps^{-1}$$



- *The B_S oscillation frequency is very high:* **$\Delta M_S > 14.4 ps^{-1}$ (95%CL)**
  - *Good proper decay time resolution is needed for frequency measurements:*
    - **$S \propto \exp(-(\Delta M_S \sigma_t)^2)$**
  - Semileptonic B_S: ~6-7k events/200pb^{-1} …

ISFT: Opposite Side Muon Tagging

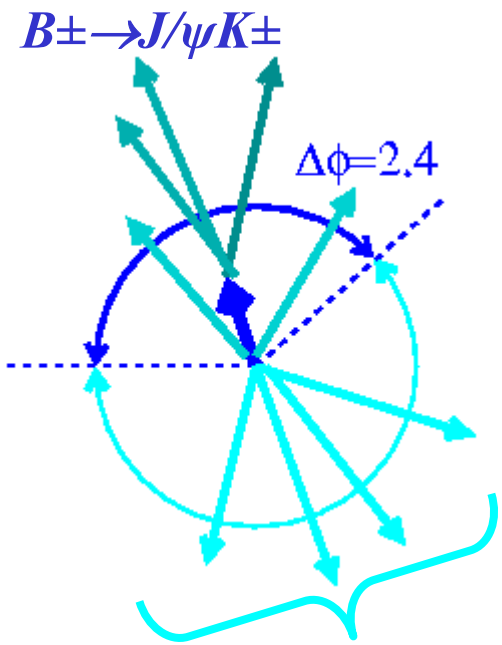


- ✓ P^T_μ > 1.9 GeV
- ✓ Q_μ – charge of muon with the highest P_t
- ✓ Classification:
  - ➢ Q_μ != Q_K : correct tag
  - ➢ Q_μ == Q_K : wrong tag
  - ➢ No muon : No tag

D0 RunII preliminary:

- ➢ **D = (57.0±19.3)%**
- ➢ **ε = (5.0±0.7)%**
- ➢ **εD^2 = (1.6±1.1)%**

ISFT: Opposite Side Jet Charge Tagging



- ✓ $P_t > 0.5$GeV
- ✓ $\Delta Z_{PV} < 2$cm
- ✓ Classifications:
  - $|Q| > 0.2$ && sign(Q) != Q_K : correct tag
  - $|Q| > 0.2$ && sign(Q) == Q_K : wrong tag
  - $|Q| < 0.2$: no tag

$$Q = \sum P_t q / \sum P_t$$

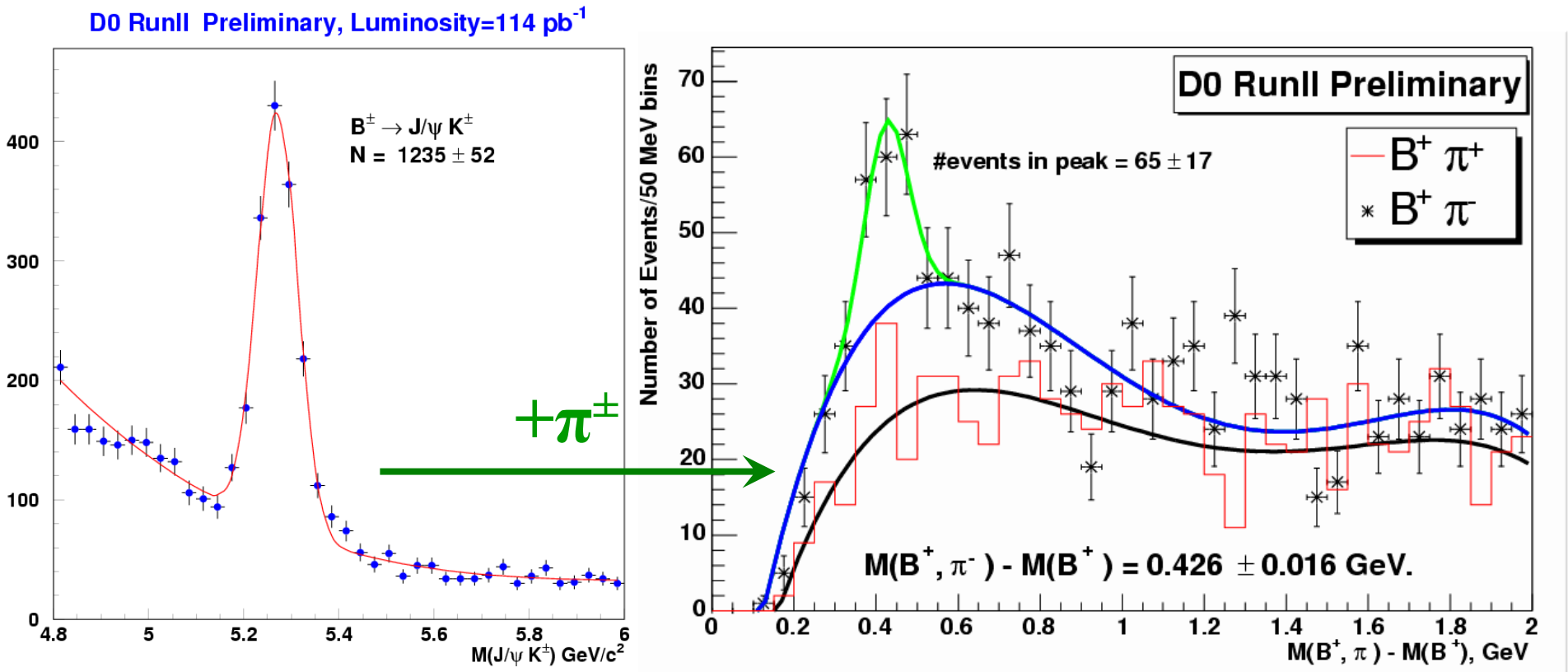
D0 RunII preliminary:

- ➢ $D = (26.7 \pm 6.8)\%$
- ➢ $\varepsilon = (46.7 \pm 2.7)\%$
- ➢ $\varepsilon D^2 = (3.3 \pm 1.7)\%$

ISFT: Same Side Tagging

- ✓ Excited B** decays into B and pion/kaon which carries the initial state flavor information

Example: $B^{**}_d \rightarrow B^+\pi^-$



Summary of Results

✓B Lifetime measurements:

Mode	τ, ps	σ_{stat}, ps	σ_{syst}, ps	ratios
Inclusive $B \to J/\psi + X$	1.562	0.013	0.045	
$B^{\pm} \to J/\psi + K^{\pm}$	1.65	0.083	0.123	
$B \to J/\psi + K^{0*}$	1.51	$^{+0.19}_{-0.17}$	0.20	τ_{Bs}/τ_{Bd}= 0.79±0.14
$B_s \to J/\psi + \phi$	1.19	$^{+0.19}_{-0.16}$	0.14	
$B \to D^0 \mu X$	1.460	0.083	------	

✓B Flavor Tagging:

Mode	ε, %	D, %	ε D^2, %
Jet Charge	46.7±2.7	26.7±6.8	3.3±1.7
Muon Tag	5.0±0.7	57.0±19.3	1.6±1.1

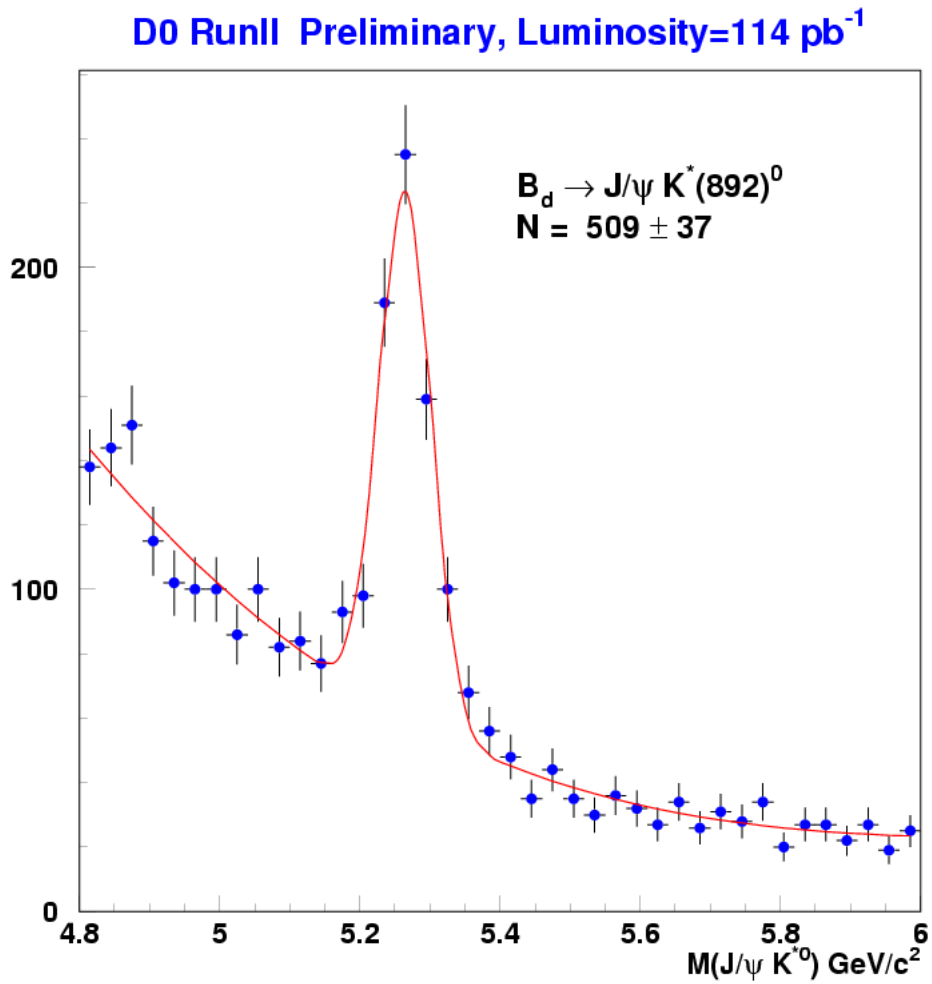
Conclusion

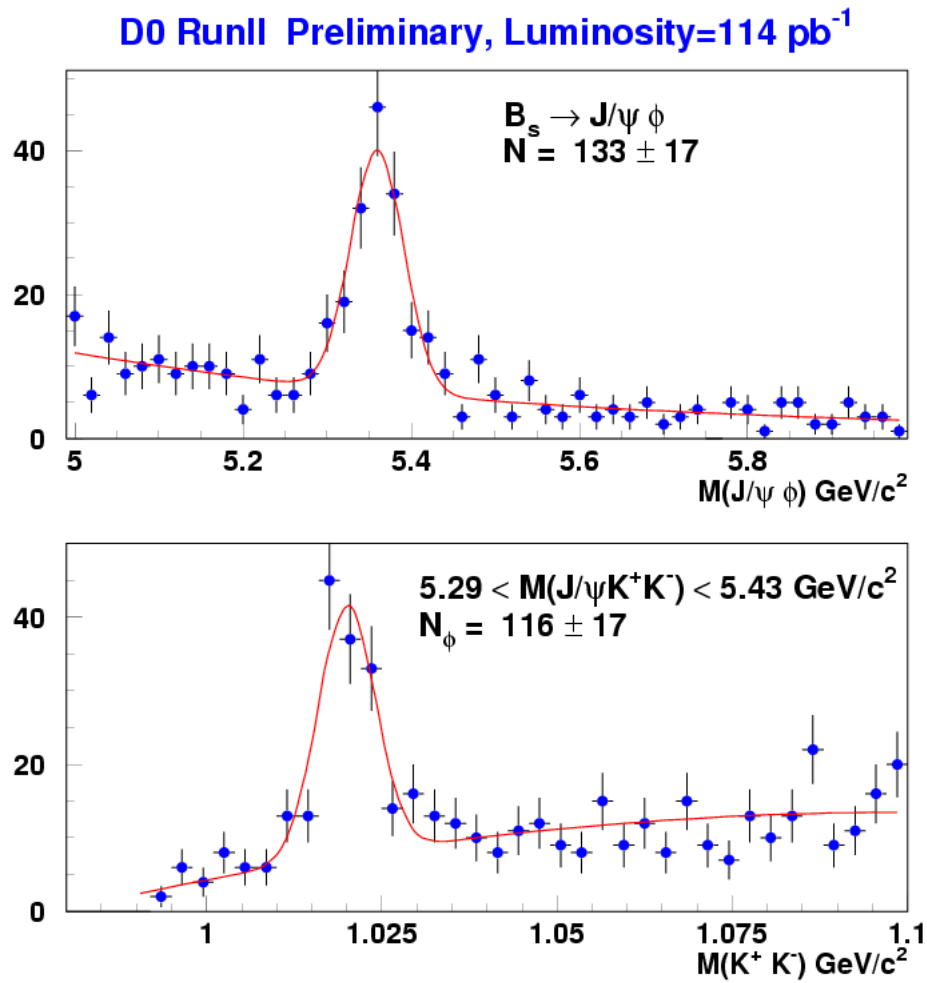
- ✓  has magnetic field and efficient tracker with large coverage
- ✓  has and continues to collect large samples for B physics
- ✓  has produced first results on B lifetime & mixing measurements and much more excellent results are ahead

Backup Slides

$B_{d,s}$ Masses ($B \to J/\psi + K0^*, \phi$)

Cuts are not the same as for LT





$B^0 \rightarrow J/\psi + K_S$